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Original Articles, Selections and Translations.

ART. I.—CONTRIBUTIONS TO ENCEPHALIC ANATOMY.

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PART I.

The Raphe and its dependencies; systemic relations of the central tubular gray matter, and the participation of the tegmental gangliæ in the motor projection system.

AN accurate knowledge of the nerve strands in the medulla oblongata and nodus encephali is the key to the comprehension of the remainder of the brain, and to acquire this knowledge a study of the raphe is indispensable. It is through the raphe that the important innervations of speech, and facial expression are placed under the control of the hemispheres; it is through the raphe, that the restiform column is metamorphosed from the posterior spinal columns, and finally, it is through this tract, and its dependencies, that the transformation of the pyramids, to certain areas of the cord is effected. The first trace of anything resembling the pyramidal decussation in the

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lowest vertebrates, is nothing more nor less than a continuation of their raphe, and in the very highest order of animals this relation is not completely effaced. I would consequently deal with the raphe and the pyramidal decussation, as a single system of fibres, in which system the decussation differs from its forerunner, the raphe, merely in bulk. What recent writers, especially the pupils of Gudden, think to gain by comparing the raphe to the decussation in the anterior spinal commissure, is not clear to me. At any rate it would prove to be a needless innovation, if the prevalent opinion that this latter decussation is itself a rudimentary continuation of the pyramidal crossing, be sustained.

Topographically the anterior boundary of the raphe lies at the altitude of the oculo-motor nerve nucleus, its lower boundary becomes gradually merged in the pyramidal decussation. Throughout its whole extent it is characterized by containing decussating and non-decussating fibres, the latter mainly give it that rectilinear appearance, by which it is recognized even with the naked eye, and in the fresh specimen. That the fibres which decussate in the basal portion of the raphe, are derived from very different sources, all authors are agreed, but with regard to the rectilinear fibres, and those which cross near the nerve nuclei, there is a difference in opinion. The master of modern (and applied) cerebral anatomy, Meynert, considers these fibres to represent his second projection system for the nuclei of the motor cranial nerves, thus he traces these *fibrae rectae* from the crura to the *oculomotorius-trochlearis nucleus*, from the vertical fibres of the pons to the *facialis abducens nucleus*, and from the anterior pyramids to the *hypoglossal* and *accessory-spinal* origins. He here doubtless laid the foundation for a great law, and a wide-spread as well as suggestive homology, but it is to be regretted that he was hastily led to assume this relation for the first nucleus mentioned. With regard to this nucleus, I would not only indorse Forel's statement, that Meynert's supposition is altogether hypothetical; but I would go further, and state that it is erroneous. It can be clearly and distinctly shown that in the latitude of the oculo-motor nucleus *no fibres leave the pes pedunculi to enter the raphe.* The most internal fibres of the pes, in this region run strictly vertical, and the large *ganglion interpedunculare* interposes its substance between these fasciculi, and the raphe; so that for the upper* extremity of the raphe, cerebrum fibres (those represented in the ganglia of the pes or cortex directly) can safely be excluded. For the trochlearis root, a similar relation probably holds good, but here, it is not so easy to come to a definite result, as the decussation of the brachium conjunctivum complicates the relations of the raphe fibres exceedingly.

The first elements comprising the raphe are two decussations; the posterior one lying just in front of the posterior longitudinal fasciculus, has been traced by Meynert to the upper quintus root, we shall describe it in detail later on; the anterior begins in that *terra incognita* behind the substantia nigra, and crosses over to occupy a more posterior position on the other side of the raphe. Interspersed with these are fibres, many of which remain on the side, whence they originate, and whose origin I trace to the ganglion interpedunculare. The further we pass down, and the clearer the anterior decussating set becomes, the more marked is a clear fasciculus running in a manner similar to the fibræ rect, that is in the anterior posterior direction, this runs in between the posterior longitudinal fasciculi of opposite sides, and terminates in the ocular-motor nerve nucleus The origin of this fasciculus is *behind* the substantia soemmeringii, and in the *lemniscus layer of the corpora quadrigemina.* I call attention to this fact the more, as I have strong reasons for supposing a similar relation to exist in the case of the trochlearis nucleus, and at least an analogy in the case of the abducens origin. This would incline me to predicate an independent innervation source for the nuclei subservient to ocular movements and accommodation, namely, that unlike those nuclei engaged in voluntary expression, articulation and phonation, they are not under the direct control of the hemispheres, but only mediately, that is through the corpora quadrigemina. This would be in perfect accordance with the experimental results obtained by Adamuck, which showed that these bodies were the seat of all associated movements of the eyeball.

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*In these papers to avoid confusion, I shall always speak of the peduncular axis as if it were a continuation of the spinal axis, for reasons given in the introduction. The upper extremity of the raphe would consequently be directed towards the anterior portion of the encephalon (as it lies in the skull); the lower extremity would be directed toward the spinal cord. Per contra, the terms anterior and posterior would be used with reference to the transverse section of the peduncular tracts, and in a general way, the anterior portion of the raphe would be its root, the posterior portion its terminus in the nerve nuclei.

Among those fibres, which Meynert traces as the second projection to the upper nucleus trigemini, I have found a few to originate in the substantia nigra. This relation is also suggestive, and will be discussed in Part II.

Lower down, as stated, the raphe is rendered obscure, by the crossing of the brachium conjunctivum, and it is not before the origin of the facial nerve is reached that the relation again becomes clear. At the altitude of the common abducens facial nucleus, the rectilinear fibres again become predominant, their terminus can be traced to the nucleus in question, and their origin is clearly in the deep transverse, and occasionally in the vertical fibres of the pons. That they consequently represent a cerebral source of innervation will appear clear to those who are familiar with the recent writings on the pons.

In how far these fibres place abducens-cells, or facialis-cells, under hemispheric control, it is impossible to state directly; inferentially, I should be inclined to suppose, for reasons to be stated, that if any of these fibres go to the abducens origin, they must be at a minimum. To the lower facial nucleus I have not been able to trace any raphe fibres, but I am satisfied that a direct transition of such fibres to the horse-shoe shaped facial root *takes place without the intervention of cells.* In this region, tho fibres of the reticular formation begin to cross the raphe, and henceforth the latter assumes its characteristic appearance of a regularly branched tree. Here, also, it becomes locally widened by the crossing of the trapezium fibres.

It again suffers a diminution in diameter at the point where the auditory nerve nucleus reaches its greatest development, that is, in the altitude of the *striæ medullares albae,* where the facial nucleus disappears, and the hypoglossal has not begun to appear. Some of the fibres in the striæ medullares can be traced to the raphe.

With the development of the inferior olivary body, and the commencing decussation of the restiform column, the raphe assumes relations which herald the approaching pyramidal decussation. It gains additional importance from its relations to the hypoglossal and accessory nerves. Here I have been able to trace the direct passage of an axis cylinder of large calibre from the anterior pyramids, to a large multipolar cell of the hypoglossal nucleus, whose peripheral process passed to the nerve roots; an incontestible proof of Meynert's projection theory.

Certain of the fibres which terminate in the hypoglossal nucleus, or the roots directly, remain on the same side of the median line whence they have originated, the majority cross to the opposite side. To what extent fibres from the reticular formation may terminate in this nucleus, or in the vago-accessory nucleus, I am unable to state precisely; I must leave this an open question. Very frequently, fibræ arcuatæ of the reticular formation, do not cross the raphe directly, but run parallel with and among its fibres for varying distances, before they emerge on the other side; that some of these may even extend as far as the nucleus is not impossible, and should such an occurrence be proven for certain of these fibres which can be traced to the hilus of the inferior olivary body, Schroeder Van der Kolk's hypothesis, regarding the relation of this body to speech coördination, would deserve renewed consideration.

There is a relative constancy in the development of the tegmental tracts, and the restiform columns in the various mammalia which I have examined, in this connection, and accordingly I have found an enlargement of the raphe, corresponding to the point where most of the fibræ arcuatæ cross, in all of them; relatively larger in the dog, as compared with man, however.

It is this area of the raphe which gradually increases in size as the decussation of the pyramids is approached. It consists at first solely of parallel bundles which cross in regular groups, entirely, and broader in front than behind, and the fasciculi emerging on either side, being separated by vertical fibres, it presents one of the most beautiful objects in cerebral anatomy, and may be likened in outline to the stem of the century plant. It is one of the most favorable localities for tracing single axis cylinders for a considerable distance. Thus far these fibres do not merit the name of a sensory decussation, and Meynert's designation to that effect in his figure 260 (Stricker's Handbüch der Gewebe-lehre II., p. 303) is erroneous. These fibres do not leave the pyramids, but represent the last decussating fibres of the restiform column, and can be clearly and distinctly traced to those fibræ arcuatæ which pass through and around the internal accessory olive. Lower down, however, a transition occurs, fibres from the outer area of the anterior pyramids, join the fasciculi described, and run with them to the *funiculi cuneati* and *funiculi graciles;* this is the commencement of the proper sensory decussation, and this gradual passage of the restiform into the pyramidal decussation, has doubtless misled Meynert. The lower down we pass, the more do pyramidal fibres replace those derived from other sources, until finally the decussation is composed of pyramidal fibres solely. How the upper finely fasciculated sensory decussation is gradually replaced by the motor, has been correctly and exhaustively described by Meynert, Clarke, and others.

It is not to be held for a moment that a sharp demarcation can be made between those areas of the pyramids which take part in the motor, and those which constitute the sensory decussation; although we can say that the outer fibres, as a rule, go to the latter, and the inner to the former, yet at the transition, fasciculi from either are inextricably mingled.

Thus the raphe is the medium for the hemispheric projection of those motor innervations, which stand in the closest relation to our intellect, and this innervation, *as a rule*, is brought down from the opposite hemisphere. It is furthermore probable, that auditory impressions travel through this tract, as well as those of taste. A relatively small lesion in this raphe will consequently produce more severe symptoms than a larger lesion in the crus or pyramids, for it cuts off entirely the influence of the will over the peripheral nerves. As an illustration of this severe effect of raphe lesions, I can point to the case of a paretic, who independently of the usual intellectual and motor disturbances characteristic of the disease from which he suffered, became, several months before his death, afflicted with complete and persistent alalia; he could not enunciate a single word, there was no agraphia or alexia, and those motions of the tongue which prevent its getting between the teeth in mastication, did not seem to be interfered with, and no trophic disturbance could be found in the tongue of any kind whatsoever. He died in an apoplectic attack, and on microscopic examination of successive sections, through the medulla and pons, an intense sclerosis of the raphe was found, occluding the whole transverse diameter, at the altitude of the hypoglossal nucleus. It occupied an approximately central position between the anterior and posterior extremities of the raphe, and beyond, that is, behind it, the vertical fibres were degenerated. The nucleus hypoglossi, as well as the outer roots, were healthy. On tracing the lesion upward, it was found to become gradually lost at the altitude of the facial origin. In this case, the sclerosis had formed around one of the long vascular twigs which run in the raphe, and, as vessels frequently form the starting point for sclerotic processes, it will be well to give that attention to this area which it deserves. I have at present a specimen of an apoplectic clot, destroying the raphe under examination. Unfortunately, no symptoms could be referred to it, as there was an immense and fatal extravasation in the corpus striatum and insula coexisting.

It may be well here to refer to the beautiful homology existing between the various fasciculi, which under the name of fibræ arcuatæ, cross the raphe throughout its whole length and depth. They all bear intimate relations to the cerebellum, and all enter into connection with ganglionic masses, which have in their turn certain structural peculiarities in common. The three fibre systems in question are the brachium conjunctivum, the trapezium, and the restiform column. The former passes through the nucleus tegmenti (Luys' *olive superieure*), the second through the superior olivary body, the last through the inferior olivary body—the olive *par excellence.* Some of these fibræ arcuatæ are derived from the tegmental tracts proper, and in them the large ganglionic cells of the reticular formation are found occupying definite positions.

This position can be only found in longitudinal sections, and is more constant in the carnivora than in man ; as with the former, they also appear better developed and more numerous. Their long axis, and their axis cylinder processes (of which I have sometimes found two, one at each end, besides the numerous protoplasmic ones) run from before backwards; that is, in parallelism with the nerve roots. What their ultimate destination is, I am not able to say with regard to all of them; there is no sharp demarcation between them and the lower facial nucleus, and the lower nuclei of the accessorius nerve; in fact, from reasons founded on a comparative study of various animals, I am disposed to look upon these latter nuclei as merely being concentrations of the scattered cells in the reticular formation. The latter, in man at least, seem to be mostly subservient depots of the lateral mixed system of Meynert.

The nerve nuclei themselves, have been so accurately described by authors, that I cannot add anything to their descriptions. I would merely call attention to a difference in the shape of certain cells which are contained in, or at least situated near, the motor nuclei. These cells are round, mostly small, and resemble somewhat the bodies found in the interspinal ganglia. They form a separate and distinct accumulation just below the hypoglossal nucleus, close to the raphe, and enter into relations with the finer fibres of the hypoglossal nucleus. They are less numerous near the accessory origin, and still less at the facial. It is highly probable that these cell groups exercise some specific, perhaps trophic, function.

A somewhat similar continuous column can be traced from the upper quintus origin down through the auditory nucleus. These cells are large, and nearly all of them can be traced to the quintus-roots ; they become less spherical and richer in processes the lower we descend, and in one region, well known as the substantia ferruginea, are deeply and constantly pigmented (in adult man.)

Not always do the nuclei give origin solely to those nerve roots whose name they bear ; thus a beautifully marked group of cells, in the outer portion of the hypoglossal nucleus, sends out a fasciculus, running a zig-zag course towards the origin of the spinal accessory nerve. These cells, and their processes, appear to possess rather the characters ascribed by Meynert to projection mechanisms, than to associating fasciculi. For physiological reasons, we would be inclined to suspect a close relation between the hypoglossal and part of the accessory origins ; and here is an anatomical basis for the idea.

In his recent painstaking and valuable contribution to cerebral anatomy, Forel takes the ground that Meynert's statements regarding the origin and termination of the tegmental tracts, are not based upon exact observation. With regard to the posterior longitudinal fasciculus, he may be correct; but I must endorse Meynert's description for all the other fasciculi, particularly the fibres derived from the thalamus. The lower vertebrata, and also the lower mammalia, such as the rodentia, exhibit clearly on axial sections, that the vertical fibres of Meynert's motor field are connected with the thalamus above (and also with the subthalamic region), and pass mainly into the lateral column of the cord below. Single axis cylinders can be traced for a great distance in fortunate sections, and few indeed can be seen to curve out of the direct path. In man the relations are less clear on account of the great extent of the brachium conjunctivum and the nucleus tegmenti. The propriety of terming this a " motor field," may be disputed (I am inclined rather to consider it a mixed tract), but the anatomical connections are facts.

Concerning the posterior longitudinal fasciculus, I have not been able to trace it beyond the altitude of the posterior commissure in any animal; thus confirming Forel's statement. I have also found it atrophic in the mole *and bat ;* and can endorse Forel's deduction, that it probably has some relation to vision, or the ocular movements, or their association with other movements. I can trace it to the deepest portion of the columns of Türck, in the cord ; in man, in addition, the lower fibres scatter and contribute to the whole area of the anterior columns. I most distinctly assert, that its fibres are not lost in the reticular formation, but can in man, as well as in animals, be clearly traced as far as, or lower down even, than the pyramidal decussation. I possess two longitudinal sections, from the peduncular axis of the cat, which show a direct termination of a fasciculus of this bundle, in the nucleus trochlearis, after separating from the main cord, a few lines higher up; its fibres, like the majority of the fibres in the posterior longitudinal fasciculus, are of the larger variety.

The peculiar relation of the abducens nerve, to which I have adverted, when speaking of the raphe, cannot be so satisfactorily settled. On sagittal sections, from the same animal, I observe fibres of a finer variety passing *into* the abducens nucleus, in the same plane, in which the peripheral roots proper pass *out.* They unquestionably connect with the nerve cells in the nucleus, and according to Meynert's scheme, and all physiological probabilities, they must place the abducens nerve under the control of some higher ganglion. *Which*, I am not prepared to say, as the upper terminus of this "second projection tract" is unknown to me. It crosses the facial root, and seems to run under the ventricular ependyma.

In no group of animals have I found the posterior longitudinal fasciculus as well developed as in the chelonia,[1] not that it is larger, but better demarcated, and more easily traced than in other animals, examined thus far. In the *Chelydra* it is a perfectly round fasciculus, which in the absence of larger nerve nuclei, runs closer to the ependyma ventriculorum than

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[*] I may here remark, that the only writer who has studied the brain of the turtle microscopically—Stieda,—has committed one very grave blunder. He states that the turtle's brain possesses no conarium (pineal body.) The *Chrysemys picta, Nannemys guttata, Chelydra serpentina, Cistudo Carolina*, and *Calemys Muhlenbergi*, all of which species I have examined, possess a distinct pineal gland; and in the brain of a *Thalassochelys* (weighing one hundred and eighty pounds, when alive, whose head I obtained through the courtesy of Dr. E. Messemer), I found this body to fully equal the human conarium in size. Unless great care is exercised in removing the dura and arachnoidea, this body is apt to be torn away, and to lack of skill in dissecting, no doubt, are attributable the statements found in several older anatomies, that the pineal gland is occasionally absent in the human being! I have never failed to find it in fifty-one brains, in which this body was sought for; but to find it, and keep it *in situ*, it is necessary to split the velum interpositum, with whose processes this body is in a close connection. The absence of the pineal body in any group of amniote vertebrates would be so atypical, that I venture this provisory correction of Stieda's statement. I can show this body in every turtle.

in the mammalia, raising the ventricular floor so as to form a columnar elevation on each side of the median grove of the fourth ventricle. It need not be stated, that this is in no wise identical with the similarly situated eminentia teres of the mammalia, which is pushed up by the curved facial root and the motor nuclei. In the *Thalassochelys marina* the upper end of this fasciculus, approximates the crescentic shape, so characteristic of the mammalian medulla and pons. We may consider the round form to represent an ancestral type, just as the *Chelydra* represents an ancestral form of the chelonia, which is documented not only in its external configuration, but also in the simple valve-like cerebellum, which contrasts markedly with the globular and massive cerebellum of the Emydæ, and the marine species, in which that body is even rudimentarily foliated.

That the posterior longitudinal fasciculus should exist so well developed in animals whose hemispheres are as poorly developed as the turtles, seems to be conclusive evidence against Meynert's view of its origin in the ansa peduncularis, especially when we bear in mind the dictum for which we are indebted to Meynert himself, that the dimensions of a fasciculus in the transverse section, depend upon the mass of grey matter with which it is connected.

(TO BE CONTINUED.)